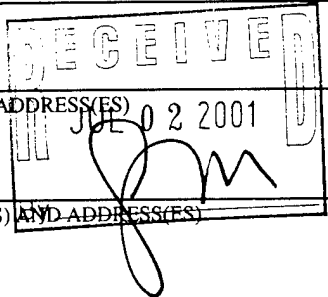


# REPORT DOCUMENTATION PAGE

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13. ABSTRACT (Maximum 200 words) Equipment is needed to establish a <b>Virtual Reality (VR)</b> facility at the University of Maryland in College Park. The facility will enable engineers to <b>Design, Simulate, Visualize and Test (DSVT)</b> the dynamics, acoustics and controls of complex <b>SMART</b> structural systems in a virtual environment. With such facility, engineers will be immersed in an audio-visually coupled tele-operated environment whereby direct interaction with and control of the DSVT process can be achieved in real time. In this manner, the behavior of synthetic structural models can be monitored by literally walking through the structure and adjusting its design parameters as needed to ensure optimal performance while satisfying design and operational requirements. For example, engineers can move electronic wands to vary the number, size, type and location of sensors and actuators in a helicopter cabin, monitor the resulting closed-loop structural vibrations visually or by haptic feedback and simultaneously listen to the radiated sound pressure field. Such manipulations of the virtual smart objects in the scene are carried out while the engineer is navigating through the helicopter cabin to ensure that the vibration and sound levels, at any critical locations, are within the acceptable limits. The facility will serve also as a platform for virtual training of students and engineers on designing and operating complex smart structural controls on site as well as through collaborative efforts with other VR sites.				
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## REPORT DOCUMENTATION PAGE (SF298)

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# VIRTUAL STRUCTURAL DYNAMICS, ACOUSTICS & CONTROL

(Grant # 40725-EG-RIP)

**A. Baz**

Mechanical Engineering Department  
University of Maryland  
College Park, MD 20742

### RESEARCH OBJECTIVES

**a. Acquire a high performance virtual reality computer system**

A high performance computer system will be acquired through this DURIP in order to be a platform for implementing state-of-the-art Computer-Aided-Design, Simulation, Visualization and Testing (CADSVT) of the dynamics, acoustics and control of complex smart structures. The ONYX2 computer System will be used to control the operation of the Computer-Automated Virtual Environment (CAVE) System to provide a virtual environment for the design, simulation, visualization and testing of smart structures.

**b. acquire a computer-automated virtual environment (CAVE) system**

A state-of-the-art Computer-Automated Virtual Environment (CAVE) system will be acquired. This system will enable the creation of the perception of a "Virtual Reality" through 3-D imagery involving sight, sound and touch.

**c. acquire computer graphics software**

A state-of-the-art computer graphics software will be acquired to operate both the Infinite Reality Computer and the CAVE system. The proposed software aims at generating interactive 2D and 3D computer graphics with toolboxes for developing virtual reality applications and deriving all VR projections, high resolution stereoscopic displays, gloves, data suits, motion sensors, haptic feedback and motion bases.

**d. develop optimum computer-aided design (cad) strategies of smart structures**

CAD strategies will be developed to optimally design Smart structures in the virtual environment of the CAVE. Emphasis will be placed on simultaneous design of structures/control systems with optimal performance. Optimal strategies for placement and sizing of control actuators/sensors will be of utmost importance.

**e. evaluate the dynamics, acoustics & control characteristics of helicopter cabins**

The dynamics, acoustics and control characteristics of helicopter cabins will be evaluated in the virtual reality environment. Particular emphasis will be placed on the characteristics of the Ultra-Sport 496 Helicopter of American Sportcopter, Inc. which represents our test articles for the ARO - MURI Grant.

**f. provide general-purpose facility for cad of smart structures**

The proposed equipment will provide a general-purpose facility for Computer-Aided Design (CAD) of Virtual Smart Structures. The facility is augmented with the facility of the

Vibration & Noise Control Laboratory at the University of Maryland. In the laboratory we have the cabin of the Ultra-Sport 496 helicopter, the Dynamic, Mechanical and Thermal Analyzer (DMTA), a scanning laser vibrometer, and a rapid prototyping machine which are acquired through previous DURIP's. With such an acquisition, the laboratory will provide comprehensive and unique design, manufacturing and testing capability of smart structures which does not exist any where in the country.

**g. enhance our present vibration & noise testing facility**

The equipment requested will enhance also our research capabilities here at the University of Maryland, and enable us designing high quality vibration and noise control systems for several DOD projects which we are currently involved in. For example, the proposed equipment will directly impact our designs of passive and active vibration and noise control systems for rotorcrafts under contracts monitored by the Army Research Office (ARO). It will also impact the design of various active and passive treatments of gun barrels under an ARO grant and of torpedoes under a grant from ONR.

**h. provide means for teaching, training & service**

Furthermore and because of our central location, the equipment requested will UNDOUBTEDLY be invaluable in providing an excellent platform for CAD of virtual smart structures for many military and civilian platforms whose vibrations and acoustic signatures must be controlled accurately. Also, the equipment requested will provide excellent means for teaching our students and training the practicing engineers that interact with us about the state-of-the-art technology of virtual reality design of vibration and noise control systems.

## **APPROACH**

**a. Develop finite element models of smart helicopter cabins**

Finite element models will be developed to simulate the interaction between the structural vibrations, interior acoustics and active/passive controls for the cabin of a helicopter. The emphasis will be placed on the cabin of the Ultra-sport helicopter 496 from American Sports-copter, Inc. as it represents the test article of our ARO-MURI grant.

The finite element models will account for the effect of the control actuators/sensors on the sound pressure field inside the helicopter cabin. Examples of the control sensors/actuators include Active Constrained Layer Damping (ACLD) treatments and Active Piezoelectric Damping Composites (APDC).

**b. Optimum sizing and placement of control sensors/actuators**

Optimal design strategies will be developed to select the optimal size and location of the control sensors/actuators in order to ensure a balance between the attenuation of the interior cabin noise and the power consumption.

**c. Develop virtual models of the helicopter cabin/smart sensors/actuators**

3-D graphical models of the helicopter cabin and the smart sensors/actuators will be developed using the OpenGL and CAVELIB software routines. The models will be projected inside the CAVE along with the contours of structural vibrations of the cabin walls and the contours of the sound pressure level inside the cabin. Projected also in the CAVE will be a stereo-audio field simulating the 3-D distribution of the sound pressure field inside the cabin. Engineers immersed in this virtual environment will be able to navigate the helicopter cabin, move along/across the cabin and monitor audio-visually the performance with and without the activation of the smart controller. The engineers will then be able move their electronic wands to modify the size, location and number of control sensors/actuators which are used to control the

vibration and noise of the helicopter. With such modifications, the engineers can virtually monitor, in real-time, the performance and determine if it is satisfying the design and operational requirements.

Similar approach will be adopted to virtually design **high-speed gun barrels**. However, collaborative virtual design procedures will be considered to utilize the experiences residing in Benet Laboratory and TACOM/TARDEC for the analysis of the dynamic of gun barrels. The VR facility will be also exercised to virtually design **quiet torpedoes** with proper interaction with the VR facility of the Applied Research Laboratory of Penn State University whenever it is ready for operation.

## **SIGNIFICANCE**

The immediate impact of the acquisition of the proposed equipment will be our current DOD research projects, in general, and on the implementation of the vibration and interior noise control of rotorcrafts, in particular.

In the near future, the impact will extend to our proposals which are currently under consideration such as the Active and Reactive Shells for controlling the vibration of gun barrels, torpedoes and aircraft airframes. Also, the equipment will enable us expanding our research activities to the area of Meso-scale control of smart structures instead of limiting ourselves to macro-scale controllers. This new area will be invaluable to DOD activities such as the local control of deformable mirrors to achieve high pointing accuracy or smart surfaces to avoid undesirable turbulence and flutter problems.

Furthermore, the impact of such new technology on our students will be invaluable especially if they were to work for DOD labs where similar equipment are in continuous use such as in Tank-Automotive & Armaments Command/ Tank-Automotive Research, Development and Engineering Center (TACOM/TARDEC) at Warren, Michigan. The students will be directly ready to use the equipment and produce results that are in continuous demand for controlling the vibration of new classes of ammunitions, rockets and missiles.

For practicing engineers, we envision that having state-of-the-art equipment will enable us conduct short courses and workshops to train those engineers on modern CAD technologies of smart structures.

Finally, the use of the equipment proposed does not limit itself to mechanical systems as the rotorcrafts but it can be extended to other systems such as passenger cars, underwater vehicles and buildings. Such diverse application of the proposed equipment is only limited by our imagination.

## **ACCOMPLISHMENTS**

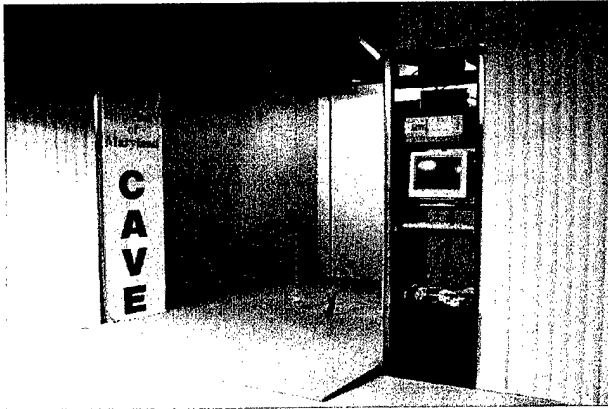
1. The system is acquired and is in operation from August 23, 2000.
2. The finite element models developed to simulate the interaction between the structural vibrations, interior acoustics and active/passive controls for the cabin of a helicopter (Ultra-sport helicopter 496 from American Sports-copter, Inc.) are now displayed in the virtual environment.

## **TECHNOLOGY TRANSFER**

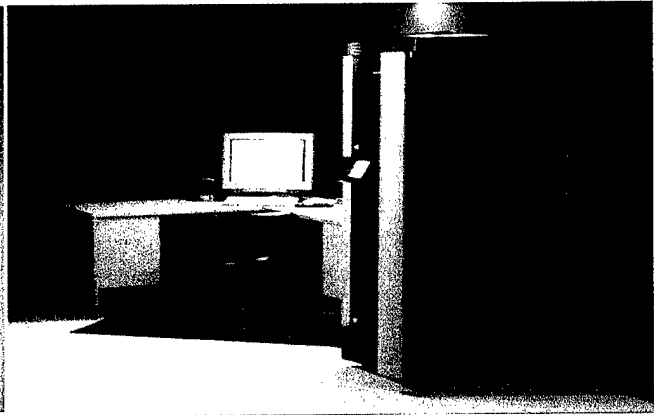
Since the operation of the Virtual Reality system, we have completed the virtual design visualization of the vibration of a **quiet torpedo** with periodic stiffeners for the Office of Naval Research under a grant # N000149910070.

Several activities are now in preparation. The first activity is to virtually design a launching mechanism for tactical bridges from tanks in collaboration with RADIANT Corporation, VA. The second activity is to collaborate with SAIC, Inc. to modify the dynamics and controls of the Ultra-sport AT-496 helicopter to be suitable to their unmanned mode of operation. SAIC, Inc. is also interested in designing the America's Cup Boat in the virtual environment.

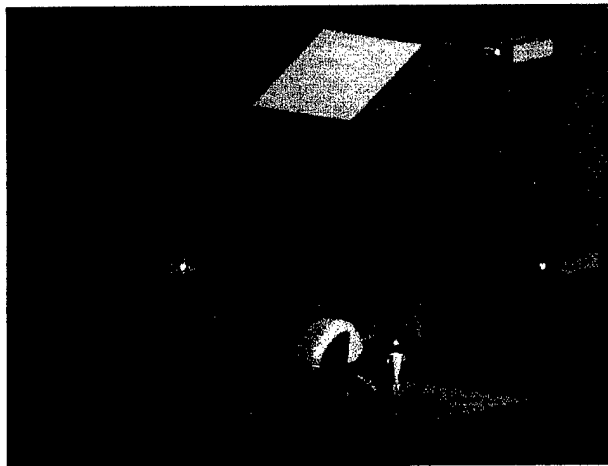
# VIRTUAL DESIGN LABORATORY



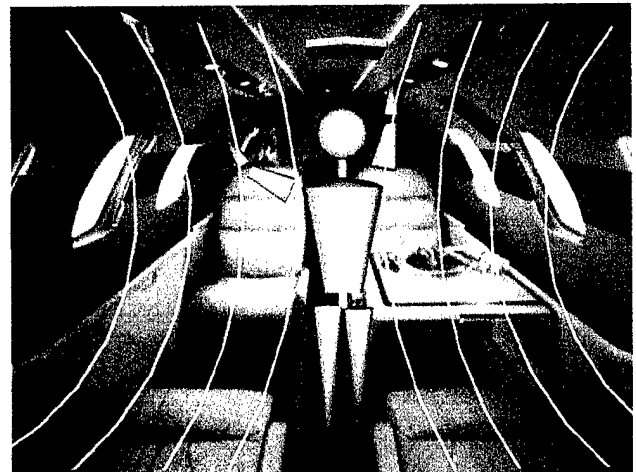
Virtual Reality CAVE System



SGI/ONYX2 Computer



Ultra-Sport Helicopter ATI-496  
Inside the CAVE



Placement of Sensor/Actuator  
inside cabin in virtual environment

**Virtual Reality Modeling  
of  
Ultra-Sport Helicopter ATI-496  
Inside the CAVE**

